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CUTTING AND DELIVERING CUT OLED DONOR SHEETS

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CUTTING AND DELIVERING CUT OLED DONOR SHEETS

FIELD OF THE INVENTION

The present invention relates to the manufacture of framed donor sheets used for use in the manufacture of organic light-emitting diode (OLED) display devices.

BACKGROUND OF THE INVENTION

OLED displays are one of the most recent flat panel display technologies and are predicted to overtake LCD display technology within the next decade. OLED displays offer brighter displays, significantly wider viewing angles, lower power requirements, and longer lifetimes than their LCD counterparts. OLED technology offers more display flexibility and alternatives to backlit LCD displays. For example, OLED displays can be made of thin, flexible materials that conform to any desired shape for specific applications. However, OLED displays and their components, known as OLED structures, which constitute subpixels of the display, are more difficult and costly to manufacture than LCD displays. It is a continuing focus of the industry to increase the throughput in an effort to lower the cost of OLED manufacturing.

Conventional OLED display devices are built on glass substrates in a manner such that a two-dimensional OLED array for image manifestation is formed. The basic OLED cell structure includes a stack of thin organic layers sandwiched between an array of anodes and a common metallic cathode. The organic layers comprise a hole transport layer (HTL), an emissive layer (EL), and an electron transport layer (ETL). When an appropriate voltage is applied to the cell, the injected holes and electrons recombine in the EL near the EL-HTL interface to produce light (electroluminescence).

The EL within a color OLED display device most commonly includes three different types of fluorescent molecules that are repeated through the EL. Red, green, and blue regions, or subpixels, are formed throughout the EL during the manufacturing process to provide a two-dimensional array of pixels. Each of the red, green, and blue subpixel sets undergoes a separate patterned deposition, for example, by evaporating a linear source through a shadow mask.

Shadow masking is a well known technology, yet it is limited in the precision of its deposition pattern and in the pattern's fill factor or aperture ratio; thus, incorporating shadow masking into a manufacturing scheme limits the achievable sharpness and resolution of the resultant display. Laser thermal transfer promises a more precise deposition pattern and higher aperture ratio; however, it has proved challenging to adapt laser thermal transfer to a throughput manufacturing line, which is necessary to warrant its use in the manufacture of cost-effective OLED display devices.

During laser thermal transfer, a donor sheet having the desired organic material is placed into close proximity to the OLED substrate within a vacuum chamber. A laser impinges through a clear support that provides physical integrity to the donor sheet and is absorbed within a light-absorbing layer contained atop the support. The conversion of the laser's energy to heat sublimates the organic material that forms the top layer of the donor sheet and thereby transfers the organic material in a desired subpixel pattern to the OLED substrate. The donor sheets are ideally fed automatically into the process such that the stoppages between depositions can be minimized.

U.S. Patent 6,485,884 provides a method for patterning oriented materials to make OLED display devices, and also provides donor sheets for use with the method, as well as methods for making the donor sheets. However, U.S. Patent 6,485,884 fails to provide a continuous way to manufacture the donor sheets. Donor sheets must be cut from a sheet of fragile web prior to being coating with the organic material layer that is subsequently deposited on the OLED display via laser thermal transfer. To provide the ease of robotic handling necessary for a high throughput process, it is also desirable to provide a continuous way of mounting the donor sheets to frames.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an effective way of delivering cut donor sheets into a frame for use in OLED manufacturing.

It is therefore another object of the invention to provide a high-throughput method for the cutting and framing of donor sheets from a roll of web for use in the manufacture of OLED display devices.

The present invention is a high-throughput system for cutting and framing donor sheets from a roll of web for use in laser thermal transfer during the manufacture of OLED display devices.

This object is achieved by a method of delivering donor sheets to be subsequently processed in the process of making an organic light-emitting device, comprising:

a) providing a roll of a flexible substrate which can either include organic layers or subsequently be coated with organic layers;

b) unrolling a predetermined length of donor and cutting the donor sheet to a size suitable for subsequent use in depositing organic layers;

c) transferring the cut donor sheet into a sheet receiver onto a frame and securing the donor sheet to the sheet receiver; and

d) delivering the sheet receiver and the secured donor sheet to a position to be further processed.

ADVANTAGES

The present invention provides an improved way of delivering cut donor sheets into frames for use in subsequent OLED manufacturing. A particular feature of the present invention is the use of cassettes for receiving frames each with a corresponding cut sheet. The cassette is then used in the OLED manufacturing process.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B illustrate perspective and side views, respectively, of a donor sheet conversion apparatus in accordance with the present invention;

FIG. 2 illustrates a manual frame-mounting scheme in accordance with the present invention;

FIG. 3 illustrates a support platform that is included in the manual frame-mounting scheme;

FIG. 4 illustrates an automatic frame-mounting apparatus in accordance with the present invention; and

FIG. 5 illustrates another embodiment of the automatic frame-mounting apparatus of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1A and 1B illustrate views of a donor sheet conversion apparatus **100** for converting a web roll **110** supported axially upon a motorized unwind spindle **116** into a plurality of donor sheets **114**. After a predetermined length of web is unrolled, donor sheets are cut from the web. Donor sheets **114** form the support for a subsequently deposited organic material layer that is later selectively transferred in an appropriate pattern via laser thermal transfer to provide the emissive material throughout a color group of subpixels within an OLED display device. It is understood that donor web 112 can be precoated with an organic material layer prior to processing on sheet donor conversion apparatus 100. Web roll **110** is supplied in the form of a large roll of a donor web **112** that is, in one example, 3 mills thick, 22 inches wide, and hundreds of yards long. Web roll **110**, as well as donor sheet **114**, in one example includes a flexible substrate that is fabricated from high-temperature polymeric material such as a thermoplastic with an aromatic backbone and is precoated with a light-absorbing layer such as metallic chromium and an optional antireflecting layer such as silicon.

Donor sheet conversion apparatus **100** further includes a drive roller **122** that pays out donor web **112** over a guide shoe **118**, a slack loop roller **120** that maintains an appropriate level of tension in donor web **112**, and a pinch roller **124** that helps to drive the forward motion of donor web **112**. Guide shoe **118** is a mechanical means of guiding donor web **112** such that donor web **112** does not run off its track while advancing. Donor sheet conversion apparatus **100** further includes a bed knife **128**, against which translates a slitter knife **132** (shown in FIG. 1B), which can rotate and is supported by a slitter knife cartridge **130** that is in turn translationally supported along a rail (not shown). A clamping mechanism **126** is provided for securing donor web **112** during the act of cutting.

Donor sheet conversion apparatus **100** can further include a hopper **136** that collects donor sheets **114** upon their singulation. Hopper **136** includes a lift plate **134** that is mounted on an elevator mechanism (not shown) for stacking singulated donor sheets **114**.

Donor sheet conversion apparatus **100** is assumed to further include an appropriate level of machine control electronics and software.

In operation, donor sheet conversion apparatus **100** converts web roll **110** to a stack of singulated donor sheets **114**. Motorized spindle **116** mounts web roll **110** and pays out donor web **112**. Slack loop roller **120** is weighted and vertically positioned so as to provide an appropriate amount of tension in donor web **112**, and so as to control the rotation of spindle **116** and the payout rate of donor web **112**. Alternately, a vacuum box looper or vacuum drum can be substituted for slack loop roller **120** and would limit surface contact with precoated donor web **112**. Drive roller **122**, along with pinch roller **124**, serve as a drive assembly that advances donor web **112** a predetermined distance and subsequently halts the translation of donor web **112** to await cutting. The predetermined distance for advancing donor web **112** before halting its translation for singulation into donor sheets **114** can be accomplished, for example, using rotary encoder counts of the rotation of drive roller **122** or direct sensor detection of the lead edge of donor web **112**. Once the translation of donor web **112** is halted, clamping mechanism **126** secures donor web **112** while slitter knife cartridge **130** translates along a rail (not shown) that forms a line of contact between slitter knife **132** and bed knife **128**. As rotating slitter knife **132** translates across bed knife **128**, a cut is made on donor web **112** that forms donor sheet **114**. Slitter knife **132** can be translated along bed knife **128** in a number of ways, including manually or with the use of a pneumatic cylinder or a motor-driven lead screw. Other cutting assemblies can be substituted for bed knife **128** and slitter knife **132**, such as a point contact shear cutter (chopper) or a laser cutting assembly. Clamping mechanism **126** can be operated manually or by an actuator. As the cut is made, donor sheet **114** is formed. Donor sheet **114** is stacked atop

previously formed donor sheets **114** in hopper **136** while lift plate **134** lowers an incremental vertical distance to accommodate the next donor sheet **114**.

The next step in preparing uncoated donor sheets **114** for the subsequently deposited organic material layer is to mount donor sheets **114** to frames. Frames can be mounted to donor sheets **114** manually in a number of ways, such as by collecting a stack of donor sheets **114** in hopper **136**, as previously described, and subsequently providing loaded hopper **136** to an operator at a work table, at which time the operator manually mounts each donor sheet **114** to a frame and forms a stack of mounted donor sheets **114** in a cassette **218**. FIG. 2 illustrates an alternate way to manually mount donor sheets **114** to frames.

FIG. 2 illustrates a manual frame-mounting scheme **200** and includes an operator **210**, a frame hopper **212** that houses a plurality of rigid frames **214**, a frame-mounted donor sheet **216** that is formed by operator **210**, the cassette **218**, and a donor sheet conversion apparatus **220**. Cassette **218** is a transport vessel capable of being pumped down to achieve a desired vacuum condition and is docked to a subsequent coating apparatus or process station such as a deposition chamber. Donor sheet conversion apparatus **220** is identical to donor sheet conversion apparatus **100**, except that hopper **136** and lift plate **134** are replaced by a support platform **222**. Support platform **222** includes an indentation for housing a frame **214** and a plateau for positioning and aligning donor sheet **114** atop frame **214**, as illustrated in FIG. 3. Frame hopper **212** can include a lift plate connected to an elevator mechanism so as to maintain the position of frames **214** near the top of frame hopper **212** for ease of manual withdrawal.

In operation, and in reference to FIGS. 2 and 3, the operator **210** is positioned in close proximity to the end of donor sheet conversion apparatus **220**. Operator **210** removes frame **214** from frame hopper **212** and fits frame **214** into an indented form on support platform **222**. The lead edge of donor web **112** is automatically cut, thereby forming donor sheet **114** that falls atop frame **214**. Operator **210** aligns donor sheet **114** to frame **214**, if necessary, and mounts the

nearer edge of donor sheet **114** to frame **214** by any number of methods, such as by using glue, double-sided tape, clamps, clips, heat, etc. Operator **210** then rotates donor sheet **114**, along with frame **214**, 180° and mounts the opposite side of donor sheet **114** to frame **214**, thereby forming frame-mounted donor sheet **216**, which the operator places into cassette **218**. In an alternate embodiment, a second operator can be included in manual frame-mounting scheme **200** to achieve higher throughput. The second operator receives donor sheets **114** having one side mounted to frames **214** from operator **210**. The second operator then mounts the opposite side of donor sheets **114** to frames **214** and places frame-mounted donor sheets **216** into cassette **218**. A variety of mechanical approaches also exist for mounting donor sheets **114** to frames **214**, as are described in reference to FIGS. 4 and 5.

FIG. 4 illustrates a frame-mounting apparatus **400** that includes an indexing dial **410**. The indexing dial **410** sequentially receives a cut sheet one at a time to a frame at the sheet receiving position on the indexing dial, and transferring each such cut donor sheet to a corresponding frame and securing each such cut donor sheet to its corresponding frame. The indexing dial **410** incrementally rotates and aligns donor sheets **114** with frames **214** to form a plurality of donor sheets with frames **416** and to subsequently form a plurality of frame-mounted donor sheets **418**. Frame-mounting apparatus **400** further includes a frame hopper **412** that houses a plurality of frames **214**, a hopper **414** that houses a plurality of donor sheets **114**, and cassette **218**. Hopper **414** can be similar or identical to hopper **136** or, alternately, can be a dual-stack hopper that houses two adjacent stacks of donor sheets **114** and enables a depleted stack to be replaced by the mechanical translation of the full stack into the depleted stack space. The empty half of hopper **414** can then be filled while donor sheets **114** are being fed into frame-mounting apparatus **400** from the non-depleted frame hopper **412** can be similar or identical to frame hopper **212** or, alternately, can be a dual-stack hopper that houses two adjacent stacks of frames **214** and enables a depleted stack to be replaced by the mechanical translation of the full stack into the depleted stack space. In such a way, increased throughput is realized by limiting the

necessity for work stoppages. Frame-mounting apparatus **400** further includes an appropriate set of robotics (not shown) for transferring frames **214** into indexing dial **410**, an appropriate set of robotics (not shown) for transferring donor sheets **114** into indexing dial **410**, an appropriate set of robotics (not shown) for mounting donor sheets **114** to frames **214**, and an appropriate set of robotics (not shown) for transferring frame-mounted donor sheets **418** into cassette **218**.

In operation, a set of robotics automatically transfers frame **214** from dual-stack frame hopper **412** into indexing dial **410**. Indexing dial **410** incrementally rotates, e.g., 90°, bringing frame **214** to a position at which a set of robotics automatically transfers donor sheet **114** from hopper **414** into indexing dial **410**, and appropriately aligns donor sheet **114** atop frame **214** to form donor sheet with frame **416**. Indexing dial **410** incrementally rotates again, bringing donor sheet with frame **416** to a position at which a set of robotics automatically mounts donor sheet **114** to frame **214**, e.g. by clamping, to form frame-mounted donor sheet **418**. Indexing dial **410** incrementally rotates again, transferring frame-mounted donor sheet **418** to a position at which a set of robotics automatically transfers frame-mounted donor sheet **418** from indexing dial **410** into cassette **218**. During each incremental stop of indexing dial **410**, a new frame **214** is robotically transferred from frame hopper **412** into indexing dial **410**, a new donor sheet **114** is robotically transferred from hopper **414** into indexing dial **410** and onto frame **214**, a new frame-mounted donor sheet **418** is formed from donor sheet with frame **416**, and a new frame-mounted donor sheet **418** is robotically unloaded from indexing dial **410** into cassette **218**. Once cassette **218** is filled with frame-mounted donor sheets **418**, cassette **218** is undocked from frame-mounting apparatus **400**, eventually to be pumped down to an appropriate level of vacuum and docked with a process chamber for organic material layer deposition. In an alternate embodiment, donor sheets **114** can be fed directly into indexing dial **410** from donor sheet conversion apparatus **100**, as described with reference to FIG. 5.

FIG. 5 illustrates a frame-mounting apparatus **500** that includes a donor sheet conversion apparatus **510** that is identical to donor sheet conversion apparatus **100** in all respects, except that hopper **136** and lift plate **134** are replaced

with a simple support platform (not shown) affixed to an indexing dial **512**. Indexing dial **512** is identical in all respects to indexing dial **410** except that the appropriate robotics for transferring donor sheets **114** from hopper **414** into frame-mounting apparatus **500** are replaced by functionality enabling an appropriate coupling between donor sheet conversion apparatus **510** and indexing dial **512**. Frame-mounting apparatus **500** further includes frame hopper **212**, frames **214**, frame-mounted donor sheets **418**, and cassette **218**. A cut line **514** is shown for illustrative purposes.

The operation of frame-mounting apparatus **500** is similar in all respects to the operation of frame-mounting apparatus **400** except that the lead edge of donor web **112** pays out directly into indexing dial **512**, a cut is made along cut line **514**, and donor sheet **114** is laid atop frame **214**. Frame-mounted donor sheets **418** are formed from donor sheets **114** and frames **214** and are transferred into cassette **218** in a manner identical to that described in reference to frame-mounting apparatus **400**.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

100	donor sheet conversion apparatus
110	web roll
112	donor web
114	donor sheet
116	motorized unwind spindle
118	guide shoe
120	slack loop roller
122	drive roller
124	pinch roller
126	clamping mechanism
128	bed knife
130	slitter knife cartridge
132	slitter knife
134	lift plate
136	hopper
200	manual frame-mounting scheme
210	operator
212	frame hopper
214	rigid frames
216	frame-mounted donor sheet
218	cassette
220	donor sheet conversion apparatus
222	support platform
400	frame-mounting apparatus
410	indexing dial
412	frame hopper
414	hopper
416	frames
418	frame-mounted donor sheets

PARTS LIST (con't)

500	frame-mounting apparatus
510	donor sheet conversion apparatus
512	indexing dial
514	cut line